

## LA-UR-21-23793

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Title: Pan-Arctic Permafrost Subsidence

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Intended for: Share with PNNL colleagues working on DOE Interface project.

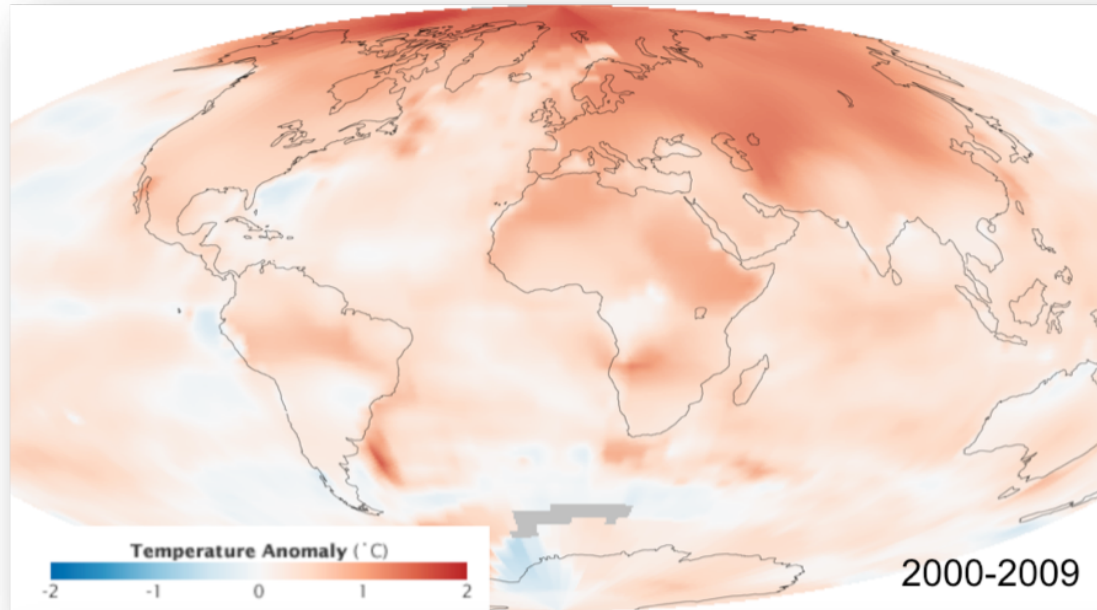
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# The Arctic is warming twice as fast as the rest of the globe, resulting in dramatic loss of ice across the Arctic system

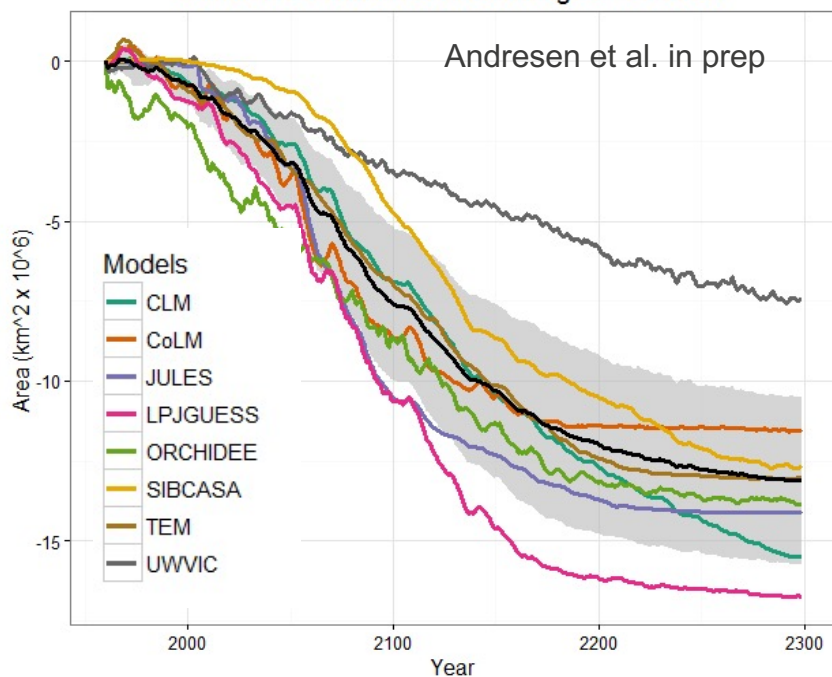


# Panarctic permafrost subsidence

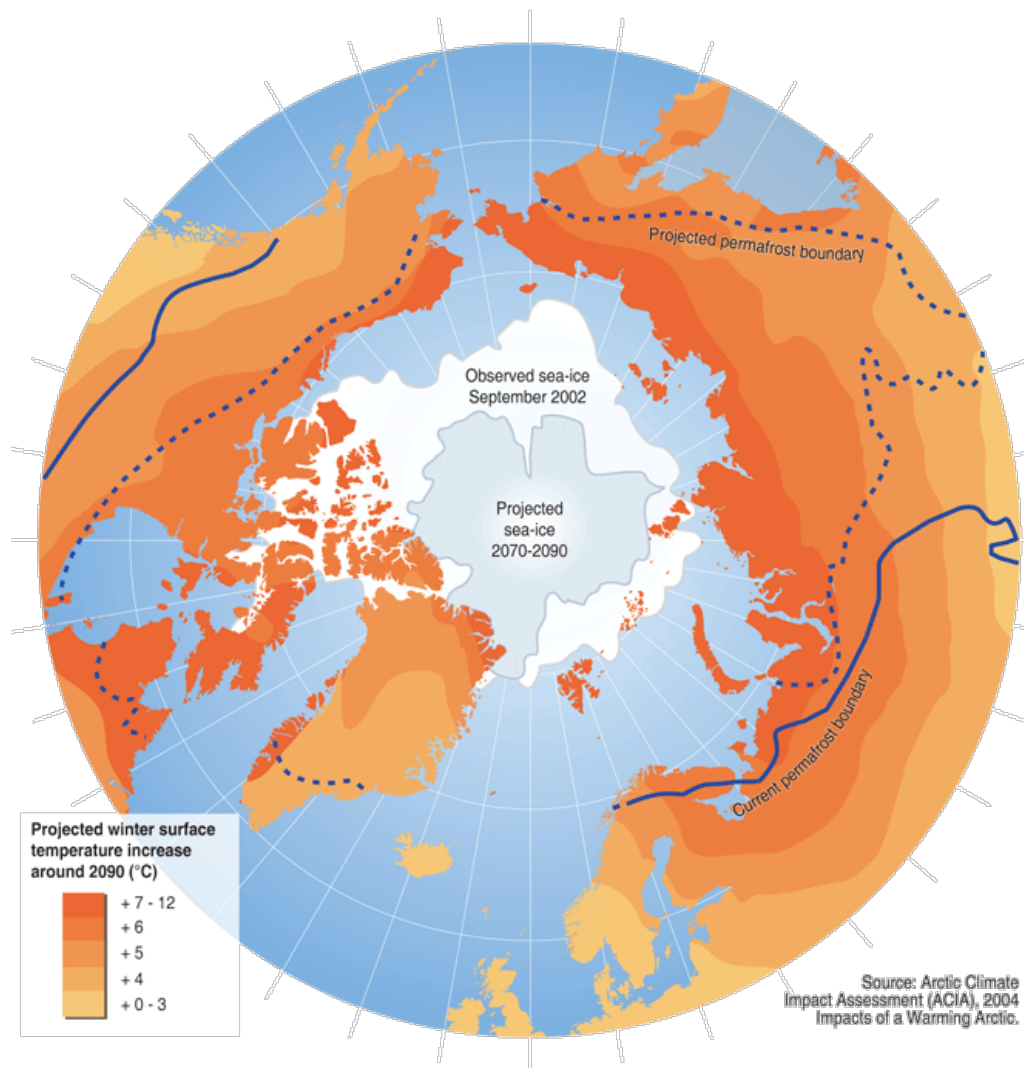
**Cathy Wilson**

# Models project 7% to 90% of permafrost could be lost by the end of the century

Simulated Permafrost Area change since 1960



- **Active layer thickness (ALT)** could increase by 30 to 300 cm by 2100
- Low sea ice years drive high air temperature and deeper ALT



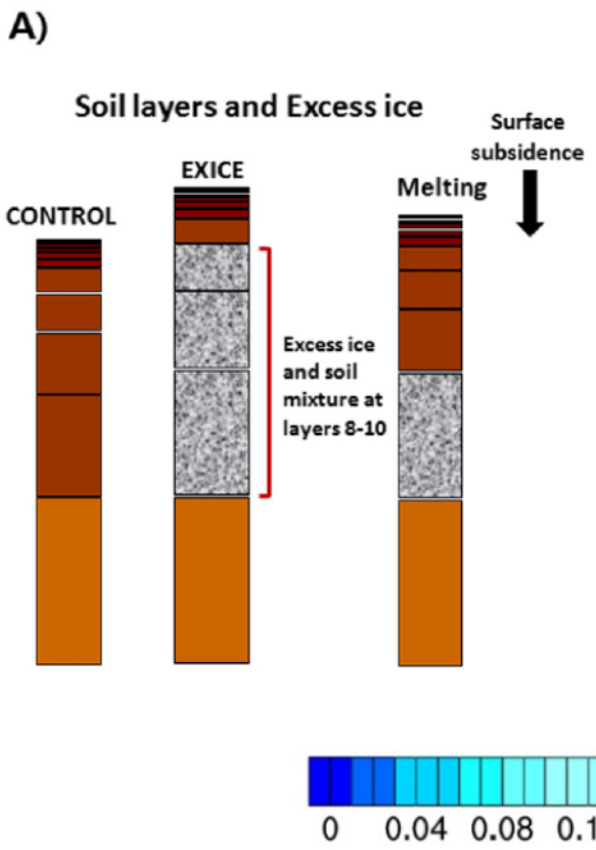
# Permafrost thaw is driving landscape degradation and infrastructure disruption through thermokarst and thermal erosion



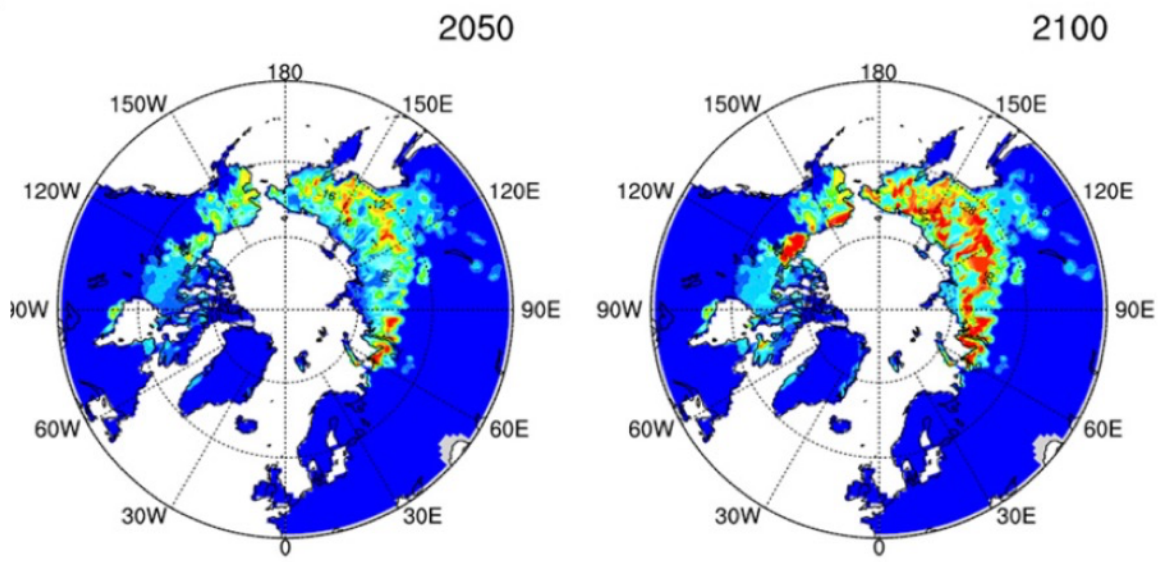
**Figure 1 | Examples of thermokarst landscapes.** Photos of (a) wetland thermokarst landscape in the Northwest Territories of Canada, with characteristic thermokarst bogs (Photo: M. Helbig), (b) lake thermokarst landscape in northern Sweden with characteristic shallow thermokarst lakes (Photo: A.B.K. Sannel) and (c) hillslope thermokarst landscape on the Taymyr Peninsula, Russia, with characteristic thermal erosion gullies (Photo: G. Hugelius).

# Previous pan-arctic modeling shows potential for significant subsidence Lee et al. 2014

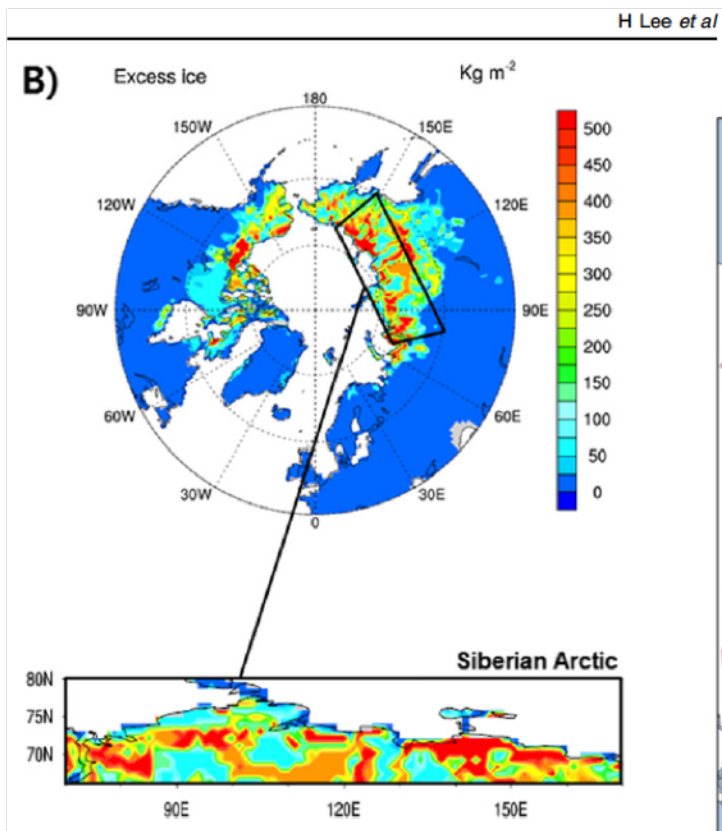
Environ. Res. Lett. 9 (2014) 124006



Projected Subsidence

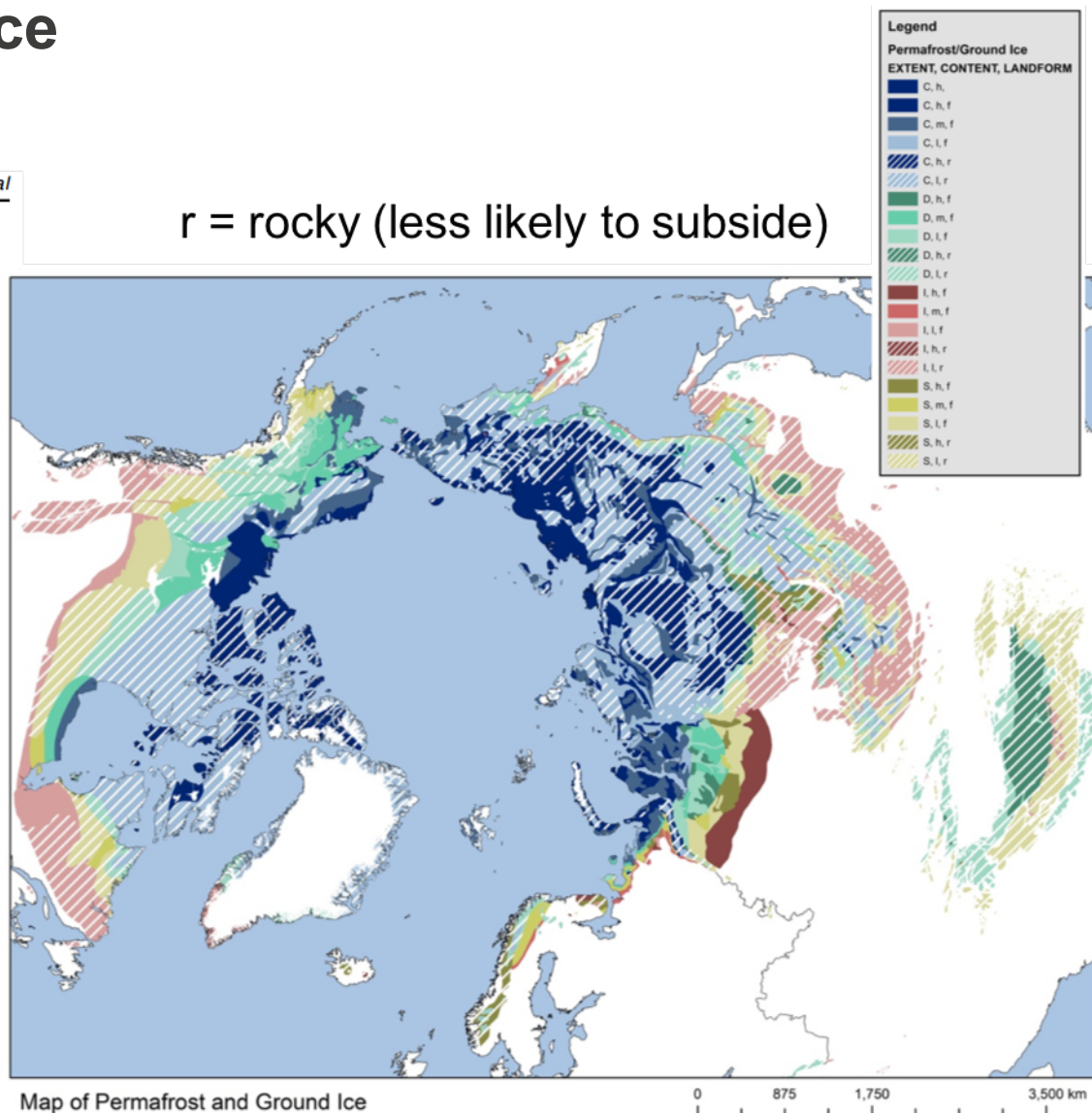


# Previous pan-arctic modeling shows potential for significant subsidence



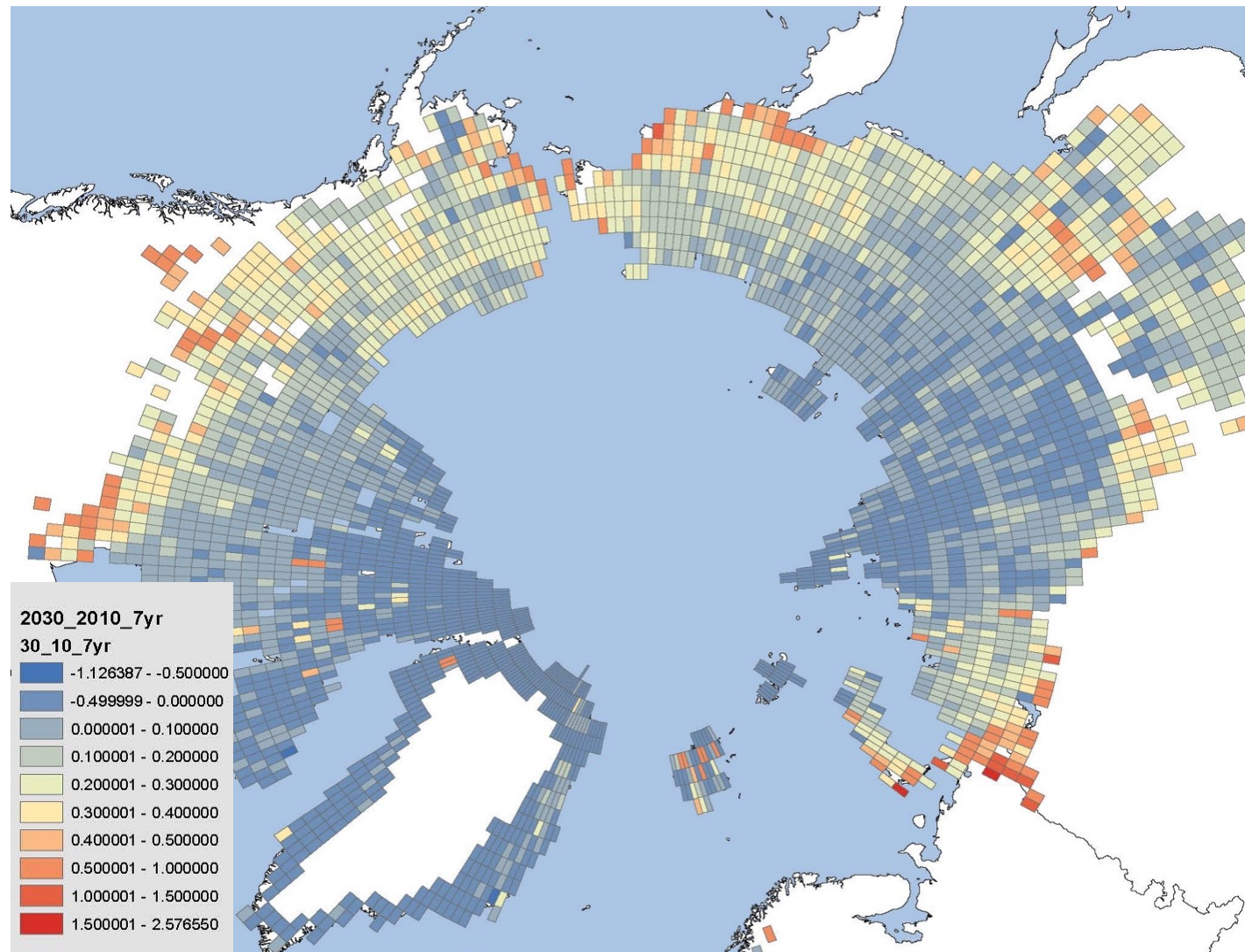
Too much ground ice in some parts of the pan-Arctic region

$r$  = rocky (less likely to subside)

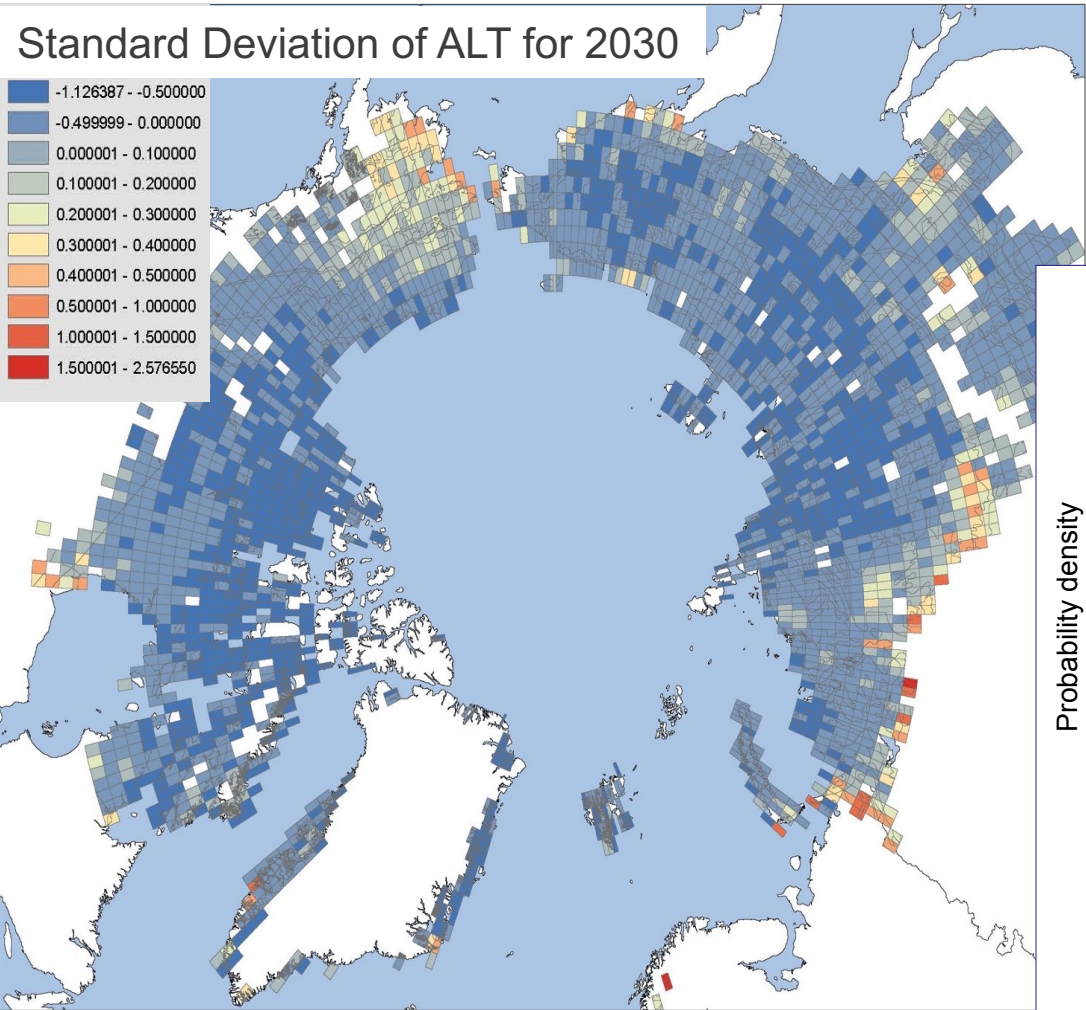


NSIDC, 2018 after Brown et al. 1997

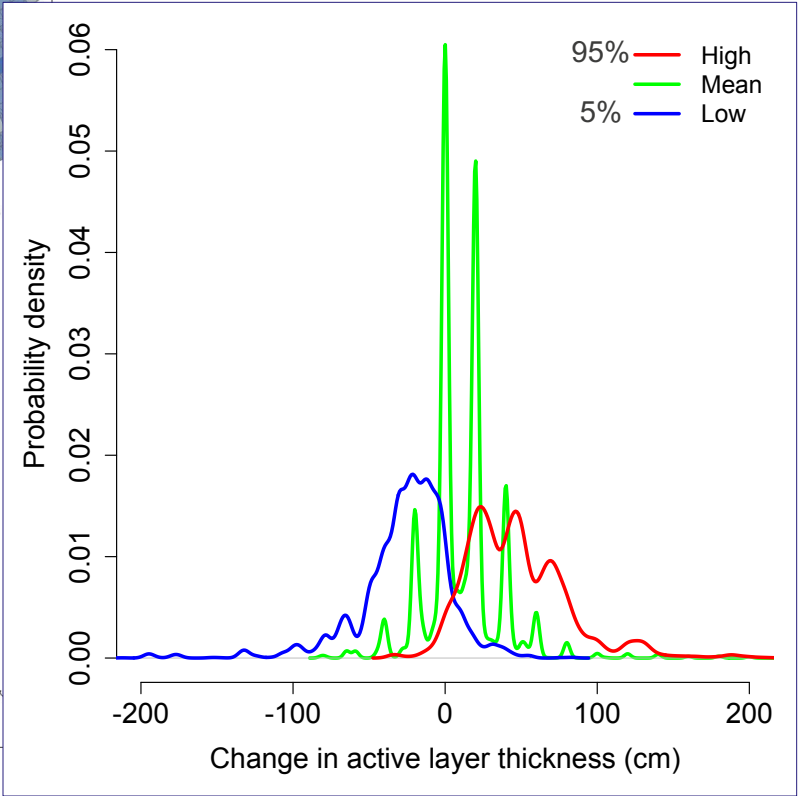
# CLM4.5 pan-Arctic simulations from PCNMIP were used to calculate change in projected ALT from 2010-2030



# Calculate standard deviation for each grid cell using 7 years of data around the years 2010 and 2030 and develop pdfs to account for variability and uncertainty



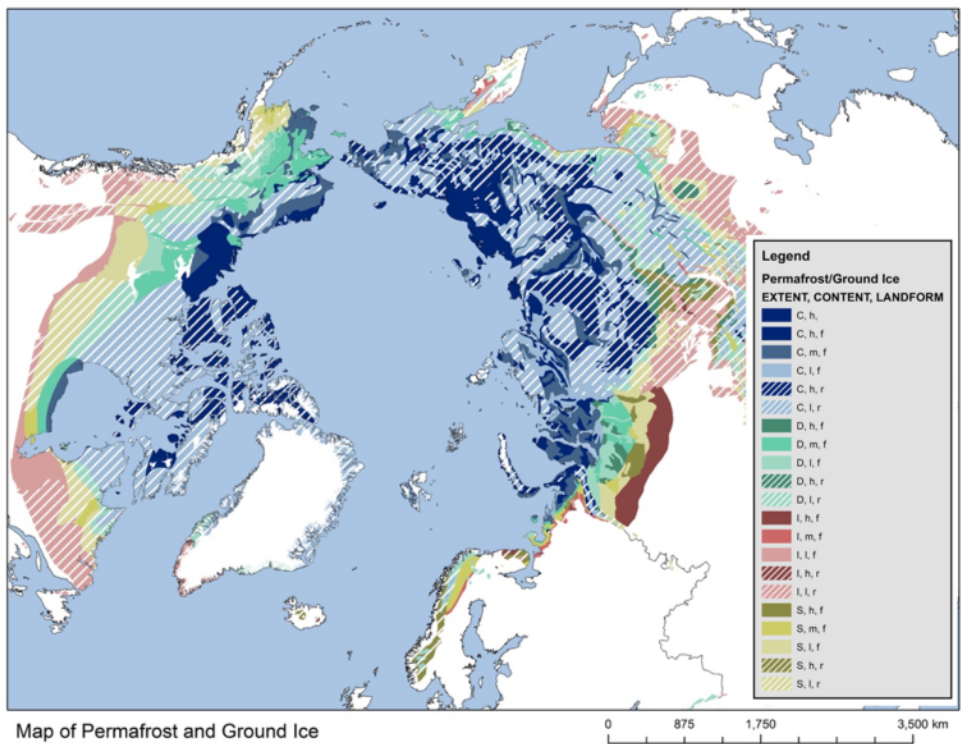
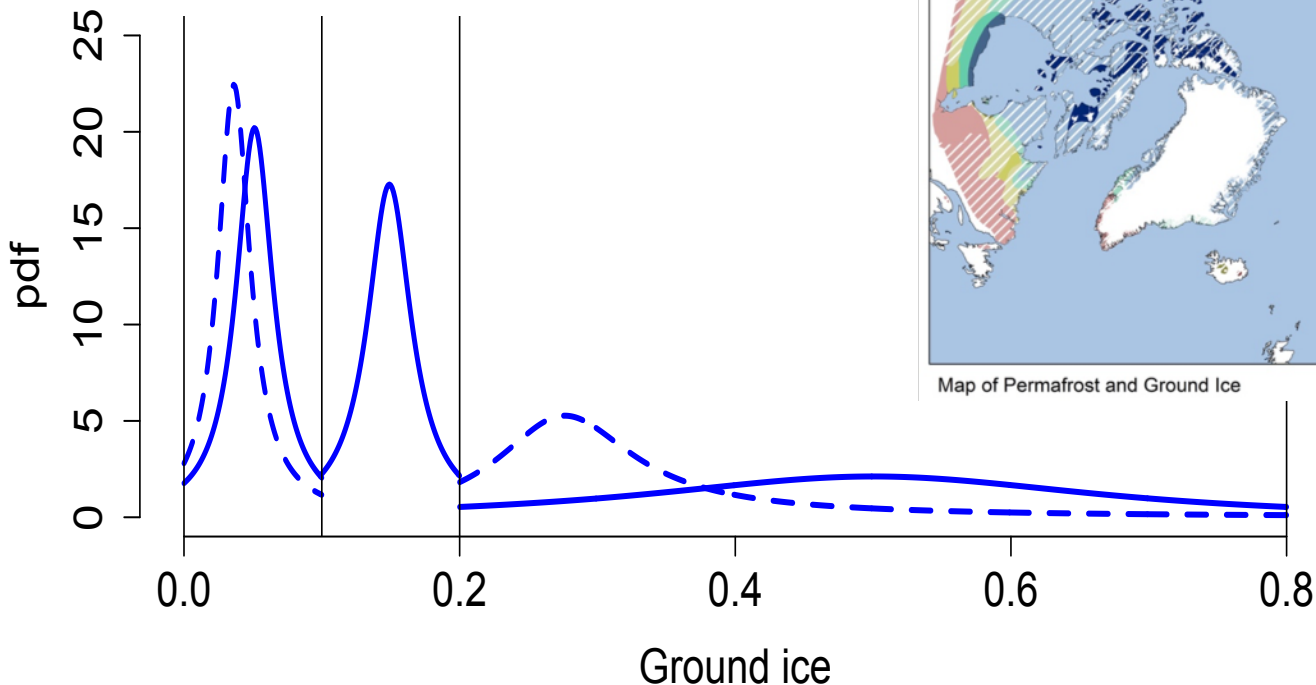
The 95<sup>th</sup> and 5<sup>th</sup> percentile pdfs for change in ALT between 2010 and 2030, aggregated over all grid cells.



# Very high uncertainty in all three quantities that define excess ground ice map units: permafrost type, **excess\*** ice content and overburden type

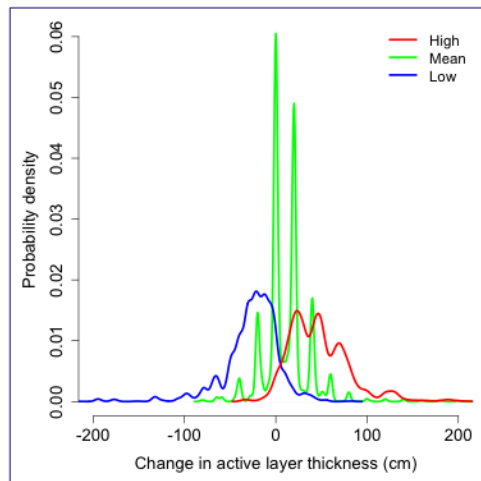
\*Pers. comm. T. Jorgenson

Flatland (Thick Overburden)		
Low (0 - 0.1)	Medium (0.1 – 0.2)	High (> 0.2)
0.05	0.15	0.5
Rocky (Thin Overburden)		
Low	Medium	High
0.025	0.075	0.25

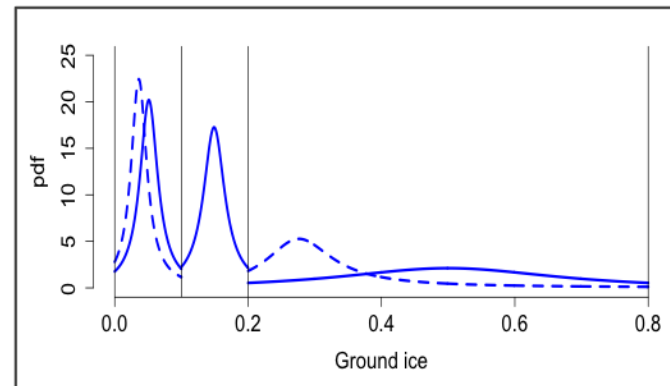


# To preserve spatial information, the CLM grid cells are "unioned" with the ground ice ArcGIS shape file polygons for subsidence calculations

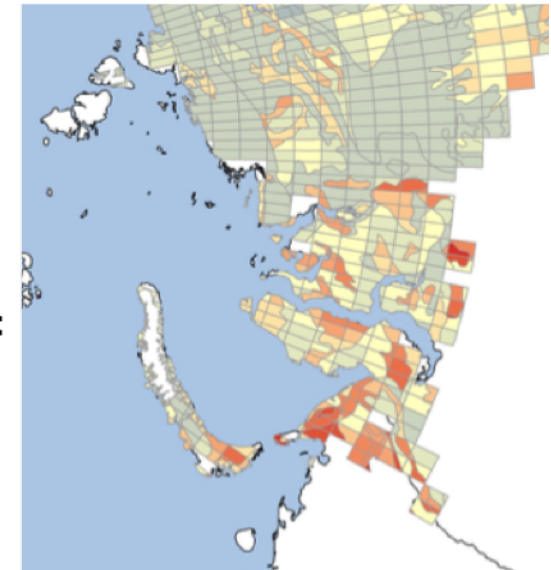
- For each ArcGIS polygon subsidence is calculated as:
  - $(ALT_{2030} - ALT_{2010}) \times \text{fraction ground ice}$ , using monte-carlo sampling of 1000 values from the PDFs of ALT and fraction ground ice
- The monte-carlo approach provides quantification of uncertainty
- Maps are generated for the mean, q5(low), q95(high), and spread (q95-q5) of the calculated subsidence



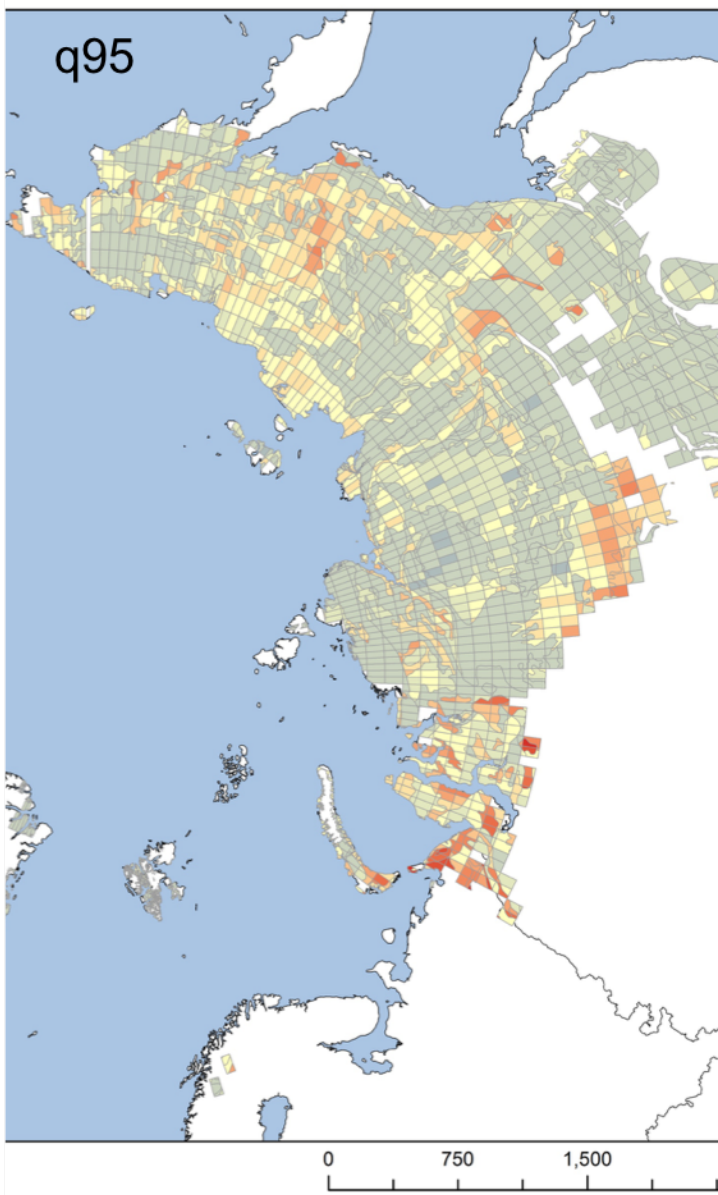
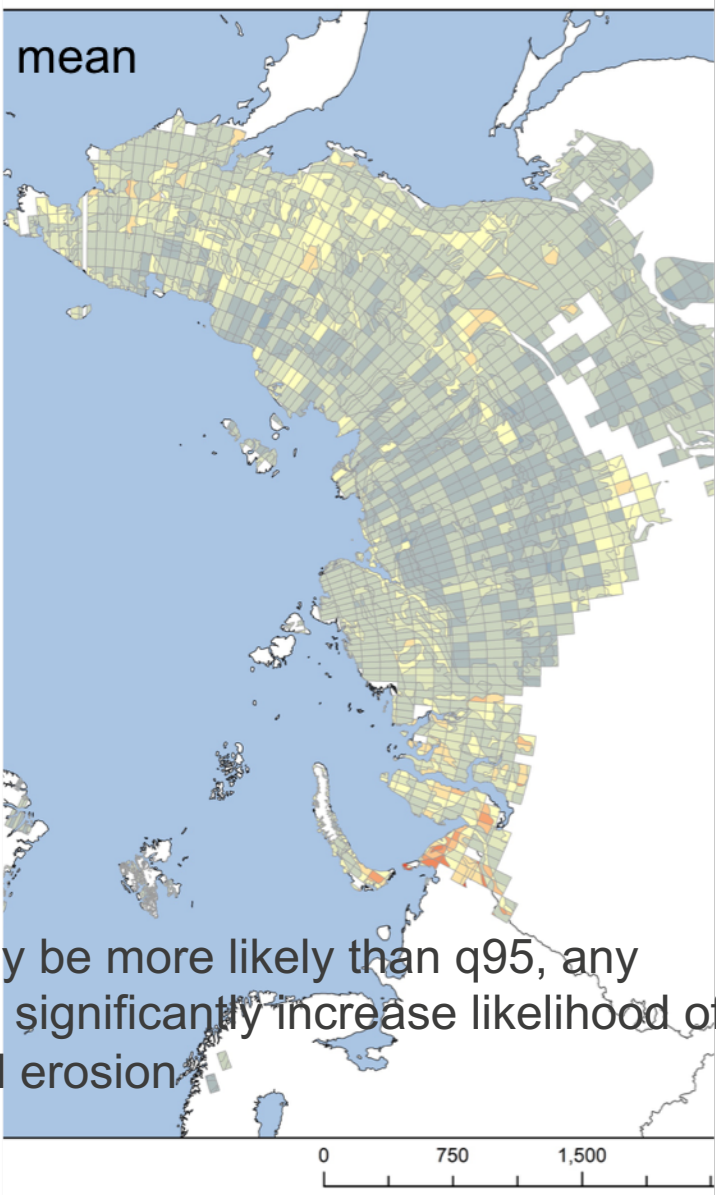
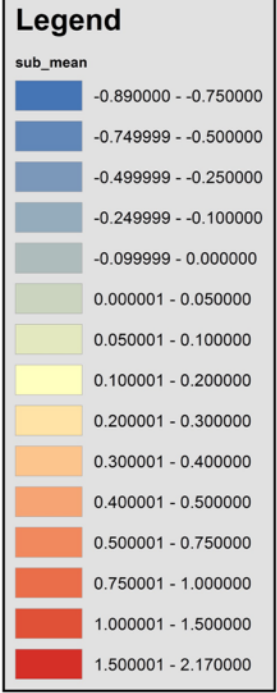
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# Mean and q95 Subsidence



Higher rates may be more likely than q95, any disturbance, will significantly increase likelihood of thermokarst and erosion

We can't distinguish between different types of thermokarst in this analysis, *but intensity of subsidence is good indication of likelihood of disruption*

